CLVL: A GLOBAL HIGH - RESOLUTION LAYERED-CLOUD DATABASE

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ABSTRACT

An important aspect of owning the weather is knowledge of cloud occurrence in a specific region. Clouds have a significant impact on electro-optical sensors aboard smart weapons. The task of understanding clouds in order use them to tactical advantage is a challenge with the current U.S. policy of rapid force projection to regions where U.S. forces may not have served before, with the result that military forecasters and planners may have only a rudimentary understanding of important mesoscale weather phenomena. Tactical planners need advance knowledge of cloud characteristics in a region before forces are deployed in order to choose appropriate weapons as well as plan bases of operations. Reconnaissance is also affected by clouds, as was clearly demonstrated in the “Great Scud Hunt” during the Gulf War. The impact of clouds on these matters is determined not only by the mean occurrence of cloudiness but by their vertical distribution as well. We have constructed a pilot dataset as a tool to address these issues.

The Climatological and Historical ANalysis of Clouds for Environmental Simulations (CHANCES) database was used, with supportive data, to produce CLVL (CHANCES LeVeLs), a multi-layer cloud database, for an initial 31 day period in July, 1994. The CLVL database is unique in that it offers a global, hourly, 5 km resolution, 8 vertical layer cloud depiction. The supportive data includes USAF High-Resolution Analysis System (HIRAS) upper-air data, surface weather observations (USAF DATSAV2 database), Special Sensor Microwave / Imager (SSM/I) precipitation retrievals from two Defense Meteorological Satellite Program (DMSP) satellites, and the U.S. Navy topographic database (ETOPO5). The CHANCES cloud detection and infrared imagery were merged with the supportive data to construct the three-dimensional cloud fields for CLVL. The HIRAS analysis and SSM/I precipitation retrievals were used to provide the vertical moisture distribution for the cloud layer assignments. The surface observations were used as input for cloud base measurements and were interpolated within the areas flagged as cloudy from the CHANCES database. Surface observations were the primary data source over land, and the HIRAS analysis and SSM/I retrievals were the primary data source over the oceans. A complementary product of precipitation, cirrus and stratus occurrence, and various data source flags was also built at the same resolution as the 8-level cloud product. The methodology used to construct the CLVL database and examples of the types of militarily relevant products which may be derived from the CLVL database are presented.

1. INTRODUCTION

Clouds play a critical role in defense-related activities. Satellite cloud climatologies (Reinke et al., 1992) are a valuable tool in recognizing preferred areas of cloud occurrence and nonoccurrence for mission planning (Reinke et al., 1993). Knowledge of the likely cloud occurrence in a specific region allows weapons and surveillance systems to be optimally placed to take advantage of the obscuration effect of clouds. Conversely, systems requiring clear conditions to operate can optimize their performance as well with high resolution cloud climatologies. Such knowledge is increasingly important with current electro-optical sensors. Simulations of cloud impacts on future military systems and training of forecasters for any part of the world can also benefit by the realistic treatment of clouds provided by high resolution cloud depictions and cloud climatologies. For contingencies where surface weather data is denied or is of poor quality, climatological properties of clouds can be a valuable tool.

The horizontal and temporal occurrence of clouds can now be studied with unprecedented global resolution by using the satellite-derived CHANCES cloud database (Vender Haar et al., 1995). Satellite-based cloud climatologies have significant advantages over those derived from surface observations of cloud cover, such as the Real Time Nephanalysis (RTNEPH). The higher resolution of the satellite-based cloud detection allows small-scale but tactically important cloud features, such as clouds anchored to topographic features, to be exploited for a military advantage. High resolution cloud climatologies for a specific region can be a useful short-term forecasting tool, and they allow a forecaster to become familiar with cloud occurrence in an unfamiliar region (Hall et al., 1996 (in this volume)).

The Chances Levels (CLVL) pilot database described in this paper extends the power of high resolution satellite cloud climatologies into the vertical dimension. Now questions such as “What is the probability of clouds above 6 km altitude in July over Sarajevo ?“ or “What is the probability of multi-layer clouds at a given location?” can be addressed. Cloud-free-line-of-sight (CFLOS) calculations with altitude dependence (e.g. Eis, 1994) are also possible with the CLVL database. In addition, the CLVL database provides researchers at CIRA a testbed with which to test and refine cloud layer retrieval algorithms on a global scale. This paper briefly describes the algorithm used to build the CLVL database and presents some examples of the types of climatological products which can be generated with such a database. More extensive documentation on the CLVL database can be found in Forsythe et al., 1996.

2. CLVL DATABASE FORMAT

The CLVL product was created as a demonstration subset from one year of the global CHANCES data. The CLVL database consists of two 8-bit images at the CHANCES 5-km global resolution for each hour of the month of July, 1994. The contents of the CLVL database are described in Table 1.

Table 1: Contents of CLVL database.

Element	Size	Contents
Cloud Layer Product	B bits	1 bit set for each layer in which cloud is present. Layers are 1.5 km apart starting at ground level.
Quality Assessment Product (QA Image)	B bits	High thin cloud or low cloud flag (from CHANCES visble I IR) Precipitation flag (from surface or SSM/I) Surface or SSM/I data use flag Moist atmosphere flag Persisted CHANCES data or error condition flag

3. INPUT DATA

CHANCES infrared (IR) temperatures and cloud detection (Vender Haar et al., 1995) are the parent data used to construct the CLVL product. The cloud/no cloud field derived in CHANCES is used as a constraint for cloud layer retrieval, with no layers retrieved where CHANCES does not indicate clouds. When cloud is indicated in the CHANCES data, additional ancillary data is brought in to assist in determining the vertical extent of the clouds. The flow of data to create the CLVL product is indicated in Figure 1. The "Global Merge Processor" is the CLVL cloud layer algorithm and will be described in section 4.

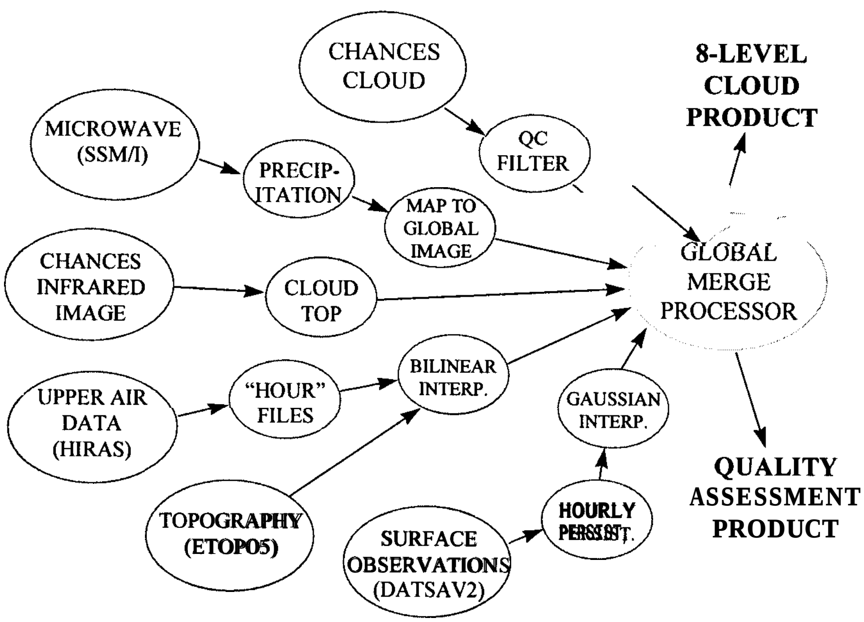

Figure 1. CLVL data flow diagram.

3.1 Satellite data

Satellite imagery that served as input to the CLVL processing was the archived CHANCES infrared image database and cloud detection database. The database consists of both geostationary and polar-orbiter data (total of eight platforms) that has been merged onto a global, 5-km, 1 -hr database. Independent cloud detection from visible (during daylight) and infrared data is stored separately in the CHANCES database.

3.2 USAF HIRAS Database

The HIRAS database consists of 2.5 degree resolution gridded fields with upper level temperature, relative humidity, and heights for mandatory levels. The database is updated every 6 hours (O, 6, 12, and 18 UTC) and was interpolated to hourly files to be matched with the l-hour resolution CHANCES database. Bilinear interpolation at each CHANCES pixel was used to construct the fields of temperature, humidity, and height at each level.

3.3 SSM/I Data

Raw SSM/I brightness temperatures from theF10andF11 instruments were mapped into the CHANCES projection and used to detect precipitation over all surface types with the algorithm of Grody (199 1). The orbit files from each instrument were broken into hourly files centered on the hour of interest.

3.4 USAF Surface Observations Database (DATSAV2)

This database is a reformatted version of standard global surface weather observations. Decoders were written to further reformat the DATSAV2 data into a more compact file structure for CLVL. Only those observational items that were of interest were saved for use in the CLVL processing. These items include station ID, location, date/time, temperature, dewpoint, cloud (sky cover) amount, cloud bases, and present weather.

Due to global patterns of weather observation reporting, there were about twice as many Surface Airways Observations (SAO) reports available at every third hour as compared to every hour (i.e., more at 0,3,9, 12, 15, 18,21 UTC) in the DATSAV2 database. This was largely due to missing observations from Eastern Bloc and Southern Hemisphere countries; Western Hemisphere nations had about the same number of observations every hour. About 7000 global observations would be available every third hour, but this number decreased to about 3500 at other hours. In order to account for this in the CLVL product, observations from the closest "third" hour were persisted to the "non-third" hours when no other observations were available. For example, at 01 UTC the observation from 00 UTC would be persisted, and at 02 UTC the observation from 03 UTC was "backward persisted".

3.5 Topography Database

Topography data is taken from the U.S. Navy ETOPO5 database. This database gives surface elevation and is on a 10-km resolution grid. This database was bilinear] y interpolated to the CHANCES resolution to determine the elevation of the CHANCES grid points, and to constrain the cloud base solution when necessary (i.e. cloud bases were not allowed to occur below the surface).

4. CLVL CLOUD LAYER ALGORITHM

This section briefly describes the steps occurring in the “Global Merge Processor” (in Figure 1), after all available data for a particular time and location has been gathered.

The first step in the production of the global layered cloud product is to determine if cloudiness exists in the CHANCES cloud/no cloud data. This occurs about 51 percent of the time on a global average. Clear points are not processed any further.

For cloudy points, the height corresponding to the IR temperature is set as the top of the cloud, hereafter referred to as Z (T). Additional clouds which might be added from the following steps are added only below this level.

Clouds classified as cirrus or stratus from the CHANCES product are only allowed to exist at the single layer defined by Z (T). Thus, these two cloud types are determined from the satellite data alone and not influenced by other data. Cirrus and stratus are only classified in the CHANCES data when visible data is available. Clouds not classified up to this step are sent to the general CLVL cloud layer assignment module, which merges in all available data (SSM/I, Surface Airways Observations (SAO), and upper air) to assign the 8 levels in the CLVL output.

A check is made to see if there is collocated SSMI/I data at the current location. If there is SSM/I data available, a precipitation testis done using the global algorithm of Grody (1991). If precipitation is indicated, a 9 x 9 pixel box (approximately 45 x 45 km) around the center of the SSM/I field-of-view is marked as precipitating. This corresponds to the SSM/I footprint size for the precipitation algorithm. If a CHANCES determined cloud is in a precipitating field-of-view, all layers below Z(T) are marked as cloudy.

Next, the SAO data is searched to find all observations within 150 km of the current location. If more than two stations are found, a Gaussian filter is used to objectively interpolate the SAO station fields (cloud bases, fog existence, precipitation existence). If only one or two SAO stations are found, a test is done to see if either is within 30 km of the current location. If so, the fields from the closest station are used. If no SAO stations are within 150 km, SAO data is not used in the cloud layer assignment. If precipitation is located in the SAO data, all levels below Z(T) are marked as cloudy. The lowest level is marked as cloudy for fog conditions. The DATSAV2 database reports up to three cloud heights, and levels corresponding to any clouds at these heights are marked as cloudy.

For non-precipitating clouds, regardless of whether they have SAO observations or not, the sounding from the HIRAS data at the mandatory levels is tested to determine if there are any clouds indicated from the relative humidity profile. The methodology to do this follows from Wang and Rossow (1995). In essence, this method looks for relative humidity in the layer greater than 84 percent, and also looks for sharp gradients between layers. Layers which are indicated to have cloud by the upper air method are marked as cloudy in the CLVL output layer product, and this occurrence is also noted in the QA image.

At this point in the CLVL cloud layer algorithm, all of the cloud layer assignments have been completed. The next step is to convert the cloud layer heights to an above ground level scale, using the ETOP05 global topography data, and to handle any unrealistic situations which may arise from this (e.g. clouds below the ground, base above cloud top). In general, error conditions occurred less than 10/0 of the time in the CLVL processing. The error flag is set in the QA image for these conditions.

Figure 2 shows a cross section through the CLVL cloud layer retrieval and a 3-dimensional rendering of the same image. The CHANCES infrared image is also shown. This is through Tropical Storm Alberto on July 3, 1994 at 16 UTC over the southeastern U.S. Note the thick clouds through the center of the tropical storm, with low scattered clouds on the west and a higher veil of clouds over the ocean to the east.

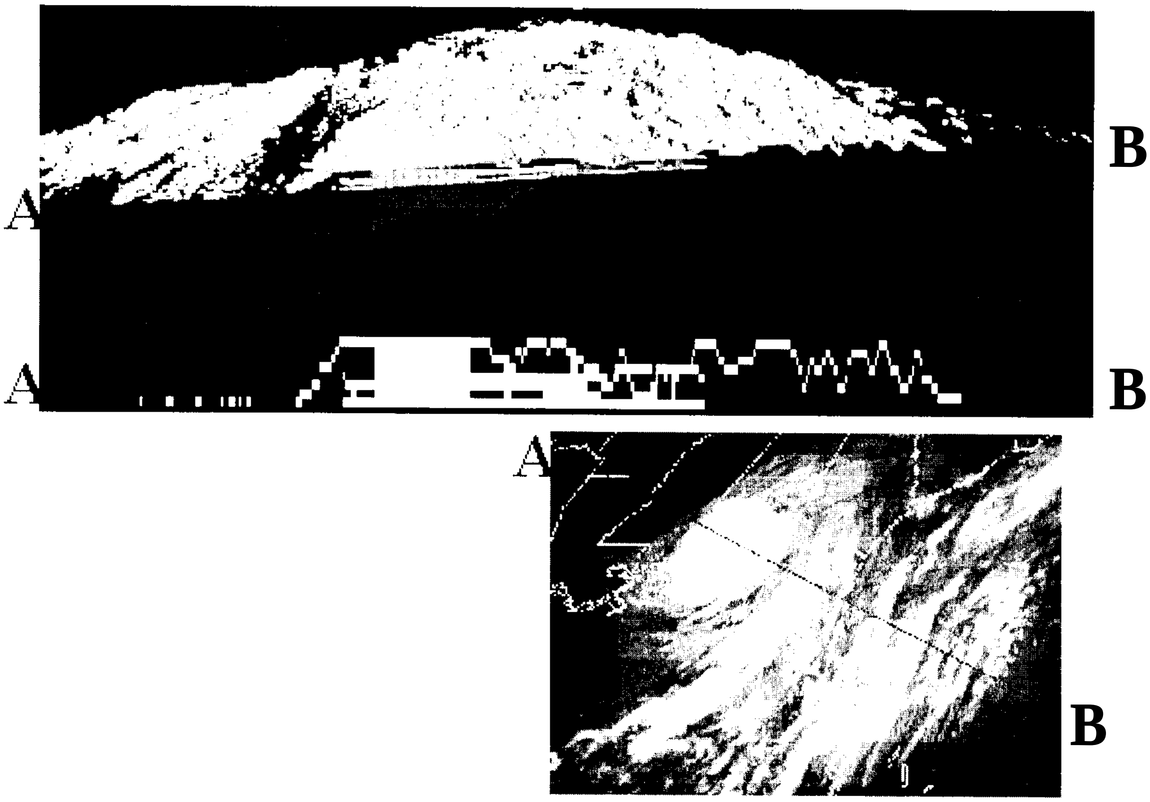

Figure 2. Sample cross-section through the 8-layer cloud product on July 3, 1994, 16 UTC. A 3-D rendering is also shown along the line A-B.

5. SAMPLE CLVL CLIMATOLOGIES

From the one month demonstration CLVL dataset from July 1994, several cloud climatologies were produced. These reveal the types of decision aids that can be generated from a layered cloud retrieval. Additional products, such as the occurrence of multiple layers of cloud in a region, can also be created with the CLVL database. There are numerous military applications of these types of products, such as reconnaissance planning and ballistic missile detection probability as a function of height.

The frequency of occurrence of cloud when cloudy in the lowest two CLVL layers is presented in Figure 3 at full CHANCES resolution for an area over Italy and the Former Yugoslavia. CLVL layered cloud retrievals from O, 6, 12, and 18 UTC were composite for the entire month of July, 1994. Note the trend towards more clouds in the lowest layer (on right), which is typical of boundary layer convective clouds. Also note the marked gradient in cloud cover from the southwest to northeast, and over land versus water. This is a reflection of topographically forced cloudiness over the mountains in the northeast.

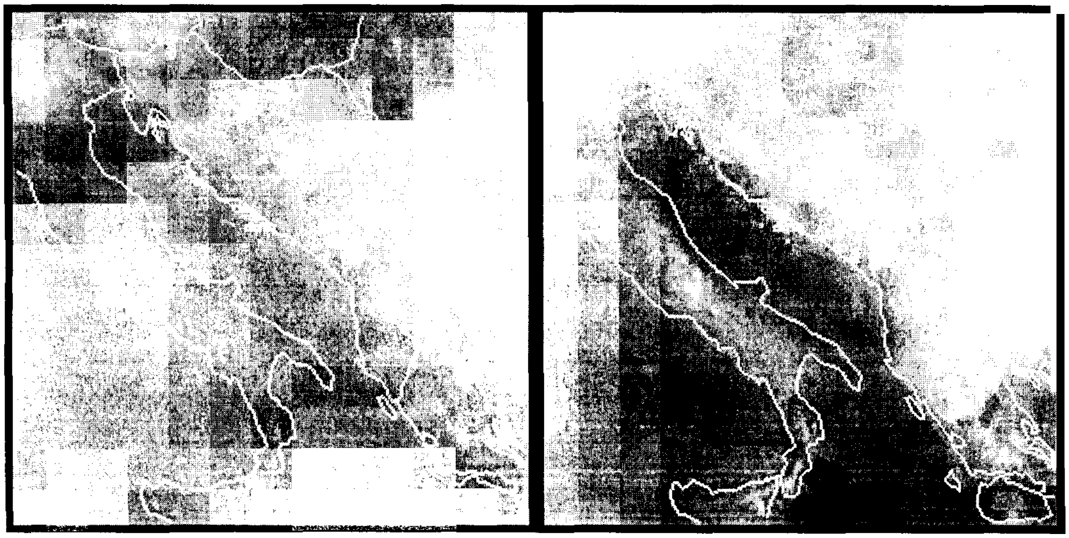

Figure 3. Examples of frequency of occurrence of cloud, when cloud is present at any CLVL layer, in the two lowest layers (1.5-3.0 km on the left and sfc- 1.5 km on the right) for July, 1994 (composite of 00,06, 12, and 18 UTC) over Italy and Former Yugoslavia. Grey shades indicate the frequency of occurrence of cloud from 0% (black) to 10OOA (white) in each layer.

The same type of analysis shown in Figure 3 can also be done on a global scale with the CLVL database. Figure 4 shows the frequency of occurrence of cloud at three selected layers (ground - 1.5 km, 4.5-6 km, > 9 km) for the globe for July, 1994 at 00, 06, 12, and 18 UTC. Figure 4 is intended to show the utility of a layered cloud climatology and is not meant to be definitive. Longer time periods would need to be analyzed for that, but essential patterns of the general circulation are apparent. The Intertropical Convergence Zone is clearly defined at all levels. There is more cloudiness close to the surface, but the decay of cloud cover with height does not occur at the same rate in all locations, for instance the central Atlantic versus the southern Atlantic ocean. Note the large regions essentially devoid of mid-level cloud over the subtropics. Knowledge of whether cloud cover is likely at a certain altitude in a region and whether it is an advantage or disadvantage could be useful for planning or avoiding air engagements in a region.

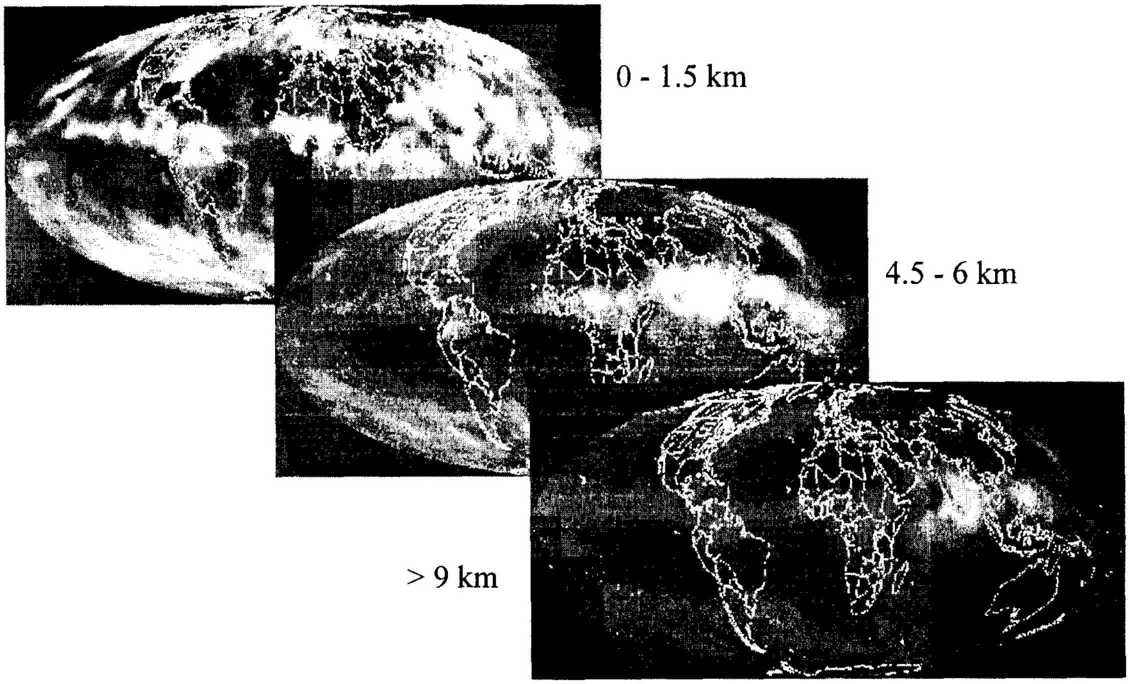

Figure 4. Global view of 3 CLVL layers shown as frequency of occurrence of cloud within a specific layer, when cloud is present in any layer, for July, 1994 (composite of 00, 06, 12, and 18 UTC). Grey shades indicate the frequency of occurrence from 0% (black) to 100% (white).

6. SUMMARY

The military has a compelling need for global cloud information. An ability to look at the global vertical occurrence of clouds together with their spatial and temporal occurrence is required. The global layered cloud CLVL demonstration database has been created at high spatial and temporal resolution to address these problems. A number of satellite and conventional weather data sources were merged together in a unique manner to create this database. All cloud detection was done from satellite data only, a distinction between CLVL and other similar products, such as the RTNEPH. The database created for this pilot study covers one month, July 1994, out of the larger CHANCES dataset.

A number of prototype high-resolution satellite cloud climatologies have been presented. By stratifying results by cloud altitude and occurrence of layers, important new militarily useful products can be created. The new views of cloud structure and occurrence hinted at in the CLVL database will provide a new understanding of how clouds impact the battlespace, and provide a tactical advantage to those who use this knowledge wisely.

7. ACKNOWLEDGMENTS

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